

Effects of high-intensity plyometric training on aerobic capacity, lower-body strength, and body composition in adolescent male volleyball players

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Abstract

Volleyball is a multidirectional sport involving approximately 250–300 explosive actions performed repeatedly during a match. Some of the most frequently performed technical actions include serving, setting, attacking, blocking, jumping, and spiking. Therefore, implementing an appropriate training program is essential to support the improvement of volleyball players' physical performance. This study aims to analyze the effect of high-intensity plyometric training on the physical performance of adolescent male volleyball players. This study used a quasi-experimental design with a pretest–posttest group design. The subjects were 24 male volleyball players from State University of Surabaya with the following inclusion criteria: age 20–25 years, body mass index (BMI) 19–23 kg/m², normal blood pressure, normal resting heart rate, normal oxygen saturation, and willingness to sign an informed consent. Subjects were randomly divided into two groups: the high-intensity plyometric exercise group (GP1; n=12) and the high-intensity plyometric exercise detraining group (GP2; n=12). The training intervention was given with an intensity of 80–90% HRmax, a frequency of three times per week for six weeks. The variables measured included aerobic capacity, maximum lower body strength, and body composition consisting of percentage of body fat, muscle mass, and bone mass using TANITA BC-545N. Data analysis was performed using an independent sample t-test with a significance level of 5%. The results showed that aerobic capacity, maximum lower body strength, muscle mass, and bone mass increased more in the GP1 group than in the GP2 group, and the GP1 group was more effective in reducing the percentage of body fat ($p \leq 0.05$). These findings indicate that high-intensity plyometric training is effective in improving the physical performance of adolescent male volleyball players.

Keywords: Plyometric Training; Physical Performance; Volleyball Players; Aerobic Capacity; Body Composition

1. Introduction

Volleyball is a sport involving high-intensity, multidirectional movements, requiring approximately 250 to 300 explosive actions performed repeatedly during a match [1]. Some of the most frequently performed technical actions in a volleyball match include serving, setting, attacking, and blocking [2], as well as jumping and spiking the ball [3]. During a match, approximately 77% to 90% of game actions involve jumping, with outside hitters and middle blockers performing between 12 and 23 jumps per set [4]. Furthermore, elite volleyball players can spike more than 40,000 times in a single competitive year [5]. The high frequency of these explosive activities demonstrates the importance of implementing a training program that can improve players' physical performance, particularly in high-intensity activities such as jumping and serving [6–7]. Therefore, monitoring volleyball players' physical performance during a

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match is crucial [8]. This monitoring can be done through continuous measurement and evaluation of athletes' performance and their physical fitness levels [8].

Plyometric training (PT) is known to be effective in increasing vertical jump height and spiking ability in volleyball players [9–10]. A study conducted by Idrizovic et al. [11] in female adolescent volleyball players with an average age of 16.6 years showed a significant increase in countermovement jump (CMJ) after PT intervention compared to a control group that only underwent a traditional training program. Meanwhile, a study conducted by Mroczek et al. [12] in male high school volleyball players detected a significant increase in the squat jump (SJ) test after a six-week PT intervention compared to a control group that did not undergo PT. Another study conducted by Mackala et al. [13] reported that a four-week PT intervention in female high school volleyball players resulted in a significant increase in the drop jump (DJ) test compared to the control group. In addition, an eight-week PT intervention focused on the upper extremities in adult volleyball players also showed a significant increase in ball spiking ability compared to the control group [14].

Several studies have shown that the implementation of PT with different periodizations, namely between four and twelve weeks, has a positive impact on the physical performance of volleyball players [14–15]. In addition, PT with different training frequencies, both ≤ 2 sessions and > 2 sessions per week, has also been reported to be able to significantly increase vertical jump height in volleyball players [10]. A systematic review conducted by Silva et al. [9] in volleyball players reported an increase in CMJ and an increase in 20-meter sprint performance after implementing PT interventions for 6 to 12 weeks with a training frequency of two to three sessions per week. A study by Gjinovci et al. [16] also reported an increase in 20-meter sprint and CMJ after PT interventions for 12 weeks with a frequency of two sessions per week. Meanwhile, Idrizovic et al. [11] reported a significant increase in CMJ after implementing PT for 12 weeks with a frequency of one session per week in adolescent volleyball players.

In contrast, a study conducted by Ramirez-Campillo et al. [17] through a randomized controlled trial compared different PT frequencies, namely one session and two sessions per week, in amateur soccer players. The results of the study showed a significant increase in CMJ compared to the drop jump (DJ), as well as in the 15-meter sprint compared to the control group. However, no significant differences were found between the two groups undergoing different PT frequencies. Similar results were also reported by Bouguezzi et al. [18] in prepubertal soccer players who compared PT frequencies of one session and two sessions per week without a control group. Performance improvements were detected in both groups, namely in SJ, CMJ, in the 5-meter sprint, and in the 10-meter sprint. However, the study also found no significant differences between the two PT groups.

Considering that PT with different training frequencies, either one session or two sessions per week, can significantly improve the physical performance of volleyball players [7,11,16], it is important to identify the optimal jumping dose by considering the age, biological maturity level, and competitive level of the athlete to minimize the risk of injury [19]. Therefore, this study aims to analyze the effect of high-intensity plyometric training on physical performance in adolescent male volleyball players.

2. Material and methods

2.1. Study design

This study used a quasi-experimental design with a pretest–posttest group design. The subjects were 24 male volleyball players from Surabaya State University (UNESA). Inclusion criteria included: being 20–25 years old, having a body mass index (BMI) between 19–23 kg/m², having normal blood pressure, normal resting heart rate, normal oxygen saturation, and being willing to participate in the study by signing an informed consent.

2.2. Data collection

The study subjects were then randomly divided into two groups: the high-intensity plyometric exercise group (GP1; n = 12) and the high-intensity plyometric exercise detraining group (GP2; n = 12). The study was conducted in one stage by providing high-intensity plyometric training intervention to the treatment group with an intensity of 80–90% HRmax, with a training frequency of three times per week for six weeks. After the intervention period was completed, measurements were taken of several physical performance variables, namely aerobic capacity, maximum lower body strength, and body composition including percentage of body fat, muscle mass, and bone mass. Body composition measurements were performed using the Tanita BC-545N device manufactured by Tanita Corporation, Tokyo, Japan.

2.3. Statistical analysis

The data analysis technique was carried out through several stages of statistical analysis. The initial stage was descriptive analysis to describe the characteristics of the research data. Next, data normality and homogeneity tests were conducted using the Shapiro–Wilk test and Levene test. If the data were normally distributed and homogeneous, the analysis was continued using parametric tests, namely the paired samples t-test to determine differences before and after the intervention within the group, and the independent sample t-test to compare differences between the two groups. All statistical tests were conducted with a significance level of 5% ($p < 0.05$). The data analysis process was carried out using IBM SPSS Statistics 25 software on the Windows operating system.

3. Results and discussion

The results of the analysis of the characteristics of all study participants are presented in Table 1. Based on the results of the analysis, no significant differences were found between the two groups in the variables of age, resting heart rate, oxygen saturation, blood pressure, body weight, height, and body mass index (BMI) ($p \geq 0.05$), so it can be concluded that the basic characteristics of the subjects in both study groups are in a homogeneous condition. Furthermore, the results of the analysis of aerobic capacity, maximum strength lower body, and body composition including the percentage of body fat, muscle mass, and bone mass between the initial measurements (pre) and after the intervention at week 6 (post) in each group are presented in Figures 1–5.

Table 1 General characteristics of research participants

Parameters	GP1 (n=12)	GP2 (n=12)	p-value
Age (yrs)	21.58±1.83	21.92±1.73	0.651
Resting heart rate (bpm)	67.25±8.13	67.33±7.22	0.979
Oxygen saturation (%)	97.58±0.99	97.33±1.16	0.576
Systolic blood pressure (mmHg)	118.50±5.69	116.17±4.06	0.262
Diastolic blood pressure (mmHg)	73.92±9.18	71.67±7.37	0.515
Weight (kg)	59.67±8.03	61.83±7.77	0.509
Hight (m)	1.67±0.04	1.69±0.06	0.219
Body mass index (kg/m ²)	21.32±2.65	21.47±2.18	0.884

Note: GP1: High-intensity plyometrics exercise group; GP2: Detraining high-intensity plyometrics exercise group

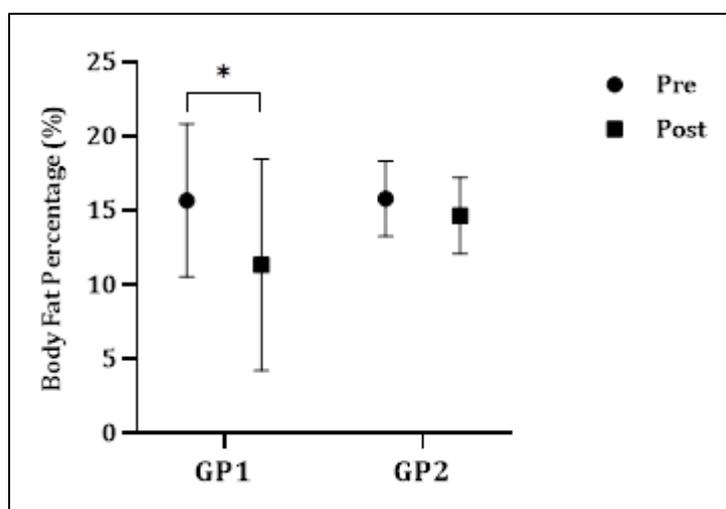


Figure 1 Assessment of the percentage of body fat at baseline (pre) and 6 weeks (post) in each group. *Indicates a significant difference with pre ($p \leq 0.05$)

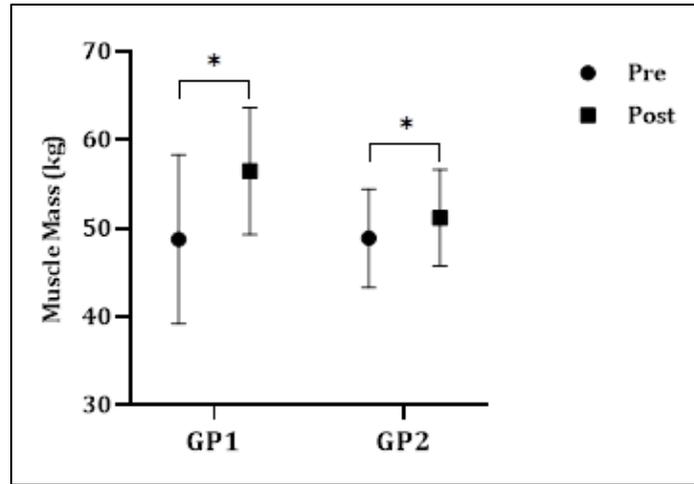


Figure 2 Baseline (pre) and 6-week (post) muscle mass assessments in each group. *Indicates a significant difference with pre ($p \leq 0.05$)

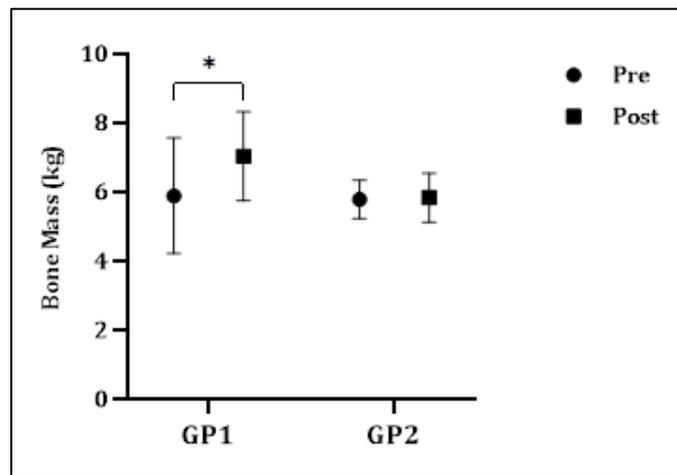


Figure 3 Baseline (pre) and 6-week (post) bone mass assessments in each group. *Indicates a significant difference with pre ($p \leq 0.05$)

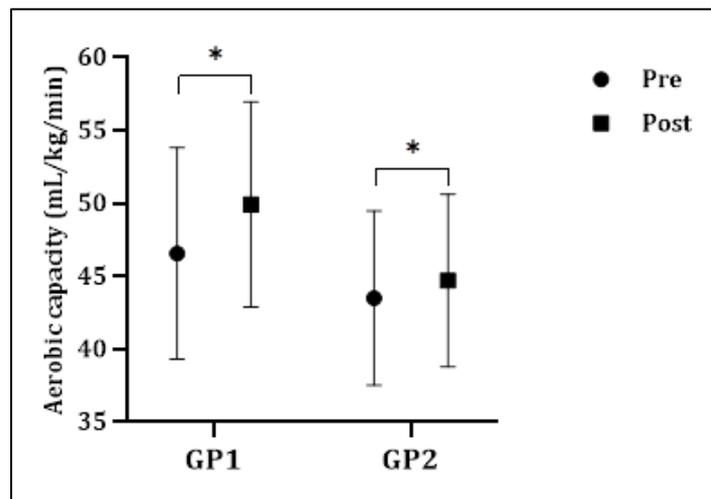


Figure 4 Baseline (pre) and 6-week (post) aerobic capacity assessments for each group. *Indicates a significant difference with pre ($p \leq 0.05$)

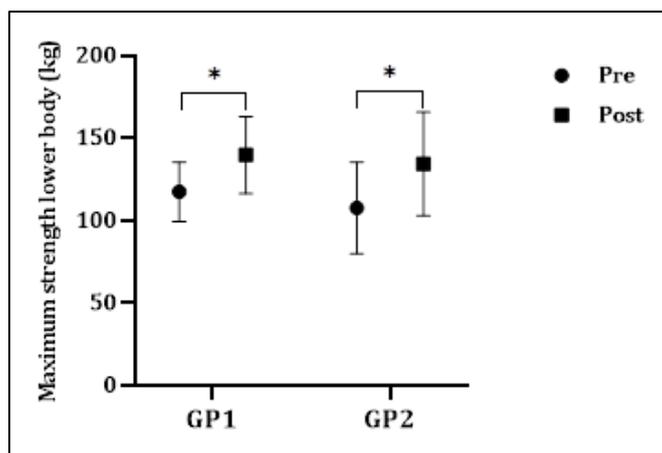


Figure 5 Baseline (pre) and 6-week (post) lower body maximum strength assessments for each group. *Indicates a significant difference from pre ($p \leq 0.05$)

The results of the comparative analysis of aerobic capacity, maximum lower body strength, and body composition including the percentage of body fat, muscle mass, and bone mass between the initial measurements (pre) and after the intervention in the 6th week (post) between groups are presented in Table 2.

Table 2 Comparison of aerobic capacity, lower-body maximum strength, and body composition baseline (pre) and week 6 (post) between groups.

Parameters	GP1 (n=12)	GP2 (n=12)	95% CI	p-value
Aerobic capacity (mL/kg/min)				
Pre	46.58±7.24	43.52±5.97	-2.55 to 8.68	0.270
Post	49.93±7.03	44.72±5.92	-0.29 to 10.72	0.062
Delta	3.35±1.23*	1.19±0.24	1.41 to 2.89	0.000
Maximum strength lower body (kg)				
Pre	117.51±17.97	107.78±27.71	-10.04 to 29.51	0.318
Post	139.89±23.39	134.46±31.32	-17.97 to 28.84	0.635
Delta	22.38±12.97	26.68±17.19	-17.20 to 8.59	0.496
Percentage of body fat (%)				
Pre	15.70±5.16	15.82±2.54	-3.56 to 3.33	0.945
Post	11.36±7.13	14.68±2.57	-7.85 to 1.22	0.143
Delta	-4.34±4.88*	-1.14±1.79	-6.32 to -0.09	0.045
Muscle mass (kg)				
Pre	48.79±9.56	48.91±5.58	-6.74 to 6.51	0.972
Post	56.52±7.21	51.22±5.47	-0.12 to 10.72	0.056
Delta	7.73±5.08*	2.32±1.89	2.17 to 8.66	0.002
Bone mass (kg)				
Pre	5.91±1.67	5.80±0.55	-0.95 to 1.16	0.833
Post	7.05±1.29*	5.85±0.71	0.32 to 2.08	0.012
Delta	1.14±0.69*	0.05±0.91	0.41 to 1.78	0.003

Note: *Indicates significant difference with GP2 group ($p \leq 0.05$).

The results of the study showed that high-intensity plyometric training significantly increased the aerobic capacity of adolescent volleyball players, as indicated by an increase in delta values in the GP1 group compared to the GP2 group ($p=0.000$). This increase in aerobic capacity may occur because high-intensity plyometric training can increase the efficiency of the cardiorespiratory system and the ability of muscles to utilize oxygen during high-intensity activities, thereby increasing VO_{2max} values in young athletes [20]. In addition, repeated high-intensity plyometric training can stimulate metabolic and neuromuscular adaptations that support increased aerobic capacity and physical performance in athletes [21].

In the variable of maximum lower body strength, the results of the study showed an increase in both groups, but there was no significant difference between the training and control groups ($p = 0.496$). This may be due to the increase in leg muscle strength in young athletes not only being influenced by plyometric training but also by growth factors, biological maturation, and routine sports training activities such as technical training and volleyball games [22]. Plyometric training is known to increase power and strength of lower extremity muscles through the stretch-shortening cycle mechanism which increases the explosive contraction ability of muscles, but the increase in maximum strength is often greater when combined with resistance training [22].

In the percentage of body fat variable, this study showed a significant decrease in the exercise group compared to the control group ($p=0.045$). The decrease in body fat percentage after a plyometric training program may occur because high-intensity training increases energy expenditure and fat metabolism during and after exercise, thus contributing to a decrease in body fat composition [23]. In addition, plyometric training performed regularly can increase muscle metabolic activity and increase fat oxidation as an energy source during physical activity [21].

The results of the study also showed that muscle mass increased significantly in the treatment group compared to the control group ($p=0.002$). This increase in muscle mass can be explained by the neuromuscular adaptation due to plyometric training which stimulates hypertrophy of type II muscle fibers which play an important role in explosive activities such as jumping and smashing in volleyball [20]. In addition, plyometric training can also increase muscle volume in adolescent athletes through increased motor unit recruitment and increased neuromuscular activity during explosive contractions [22].

In the bone mass variable, the results of the study showed a significant increase in the exercise group compared to the control group ($p=0.003$). This can be explained because plyometric training includes weight-bearing exercises with high mechanical loads that can stimulate bone remodeling by increasing osteoblast activity and increasing bone mineral density [23]. The repeated jumping and landing activities during plyometric training produce mechanical forces that can increase bone structural adaptation and strengthen the musculoskeletal system in adolescent athletes [23].

Overall, the results of this study indicate that high-intensity plyometric training has a positive effect on the physical performance of adolescent volleyball players, particularly on aerobic capacity, body composition, muscle mass, and bone mass. This finding is in line with the results of a meta-analysis which showed that plyometric training provides significant improvements in various components of physical fitness such as muscle power, speed, and jumping performance in volleyball athletes [20]. Thus, a high-intensity plyometric training program can be an effective training method to improve the physical performance of adolescent volleyball players because it can increase explosive ability, more optimal body composition, and physiological capacity of athletes.

4. Conclusion

This study shows that high-intensity plyometric training has a positive effect on improving physical performance in adolescent male volleyball players. The six-week training intervention was proven to increase aerobic capacity, maximum lower body strength, and improve body composition, including decreasing the percentage of body fat and increasing muscle and bone mass. Therefore, a high-intensity plyometric training program can be recommended as an effective training method to improve the physical performance of adolescent volleyball players.

Compliance with ethical standards

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Disclosure of Conflict of interest

The authors declare no competing interests in this study.

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